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Process optimization of mechanically expressed soursop(Annonamuricata) seeds oil using response surface methodology

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ABSTRACT

Soursop seed is an economically important oil seed which contains 34.26% oil useful as feed stock for food and many industrial applications. This research study focused on optimization of oil expression process conditions from soursop seed oil using Response Surface Methodology (RSM). From the design software employed, 30 experimental runs were conducted to determine the effect of process variables and the reciprocal reaction on oil yield. A quadratic polynomial and the ANOVA test showed the model to be remarkably significant ($p<0.05$). The highest oil yield of 29.42% was obtained when soursop seeds were conditioned to a moisture content of 15% wet basis, heated at 80^{o}C for 25 mins at a pressing time of 6 mins. Predicted optimum oil yield of 29.38% at moisture content of 16.52% wet basis, temperature of 82.56^{o}C, duration of 22.35 mins and pressing time of 6.57 mins was obtained. Under these optimal conditions, the experimental value was 29.38% which was in agreement with those predicted by computation.Mathematical models were developed relating processing factors to oilyield. Coefficient of determination (R^2) for the oil yield was 0.84. The deviations between experimental and predicted values ranged from 0.01- 4.07 for oil yield. It was ascertained that the processing parameters (moisture content, pressing time, heating temperature and heating time) had significant influence on the quantity of oil recovery from soursop seeds.

Keywords: *Soursop (Annonamauricata); Oil yield;Optimization; Processing conditions.*

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I. INTRODUCTION

Vegetable oils has found its imperativeness in meeting universal nutritional demands and are also harnessed for many food and other industrial needs including its potential benefits in health effects (Idouraineet al., 1996). Vegetable oils portrays excellent qualities to be used as raw materials for industries like food (for their nutritional value), energetic (when converted into renewable biofuels), or chemical (detergent, soaps, cosmetics, insecticides, or material industries, film-forming substances like varnishes, paints,margarine, plastics, cake, biscuit and so on). According to research, it is reported that, a good percentage of human's daily consumption is made up of vegetable oil (Jolivetet al., 2013).

Soursop (Annonamuricata) is said to be a distinctive kind of fruit. It has a greenish skin and it's slightly hard with scattered spines when unripe, whereas the ripe fruit has a soft yellowish green skin also with soft spines. The comestible flesh is hard and white when it is unripe but will turn soft, adhesive and creamy as it ripens, with fibrous membranes. Soursop is mostly consumed as fresh fruits. It is said to be cultivated mainly in home gardens.Soursopcontains a good number of ovate seeds with a smooth, shiny texture interspaced within the flesh (Okoro and Osunde, 2013).

According to review of literature, several research works done on soursop have been tailored majorly on medicinal and on the nutritional constituent of the pulp and leaves (Elavarasanet al., 2014) and also on the chemical constituent of the seeds (Cvjetkoet al., 2012).

Zahaet al. (2016) worked on fatty acid analysis, antioxidant and biological activity of fixed oil of soursop (Annonamuricata) seeds. Also, several research reports have been published on oil extraction from agricultural oil seeds on different methods of oil extraction to include, aqueous enzymatic extraction method and solvent extraction methods (Mohammed et al. 2003; Orhevbaet al. 2013; Adejumoet al. 2013).

Adepojuet al.(2014) worked on solvent extraction of oil from soursop oilseed and its quality characterization.

When mechanical method of oil extraction is employed, it is essential that the optimum preliminary processing parameters be considered before expression.This will help in obtaining more efficient expression process of vegetable oil from oil bearing seeds (Ibrahim and Onwualu, 2005; Mwithiga and Moriasi, 2007). The report ofFakayode and Ajav (2016) on moringa seed revealed that processing parameters to include; moisture content, heating temperature, heating time and applied pressure has significant effect on yield of oil during expression. Therefore, they recommended that in order to obtain optimum oil recovery and least residual oil in the cake, it is imperative to control these processing parameters during the process of oil expression. If these processing parameters are not taken into consideration, checked and properly controlled, it could result in low yield and low quality fats and oil during expression. To this end, achieving efficient processing for higher yield and to obtain cheaper end product, these processing parameters must be employed.

Some of the reports from researchers on different oil seeds include; Fakayode and Ajav (2016) on moringa seeds; Ajav and Olatunde (2011) on groundnut; Sivalaet al. (1992) on rice bran; Adepojuet al (2014) on soursop seeds; Adekola (1991) on coconut; Mwithiga and Moriasi (2007) on soybean; Udoh (2017) on soursop seed; Reddy and Bohle (1993) on mustard seeds ; Southwellet al. (1990) on avocado fruit; Bamgboyo and Adejumo (2011) on roselle seeds; Abidakunet al. (2012) on dika nut.

A deep study of literature has revealed that, to date, the optimisation of the oil expression process conditions from soursop seeds has not yet been reported. Also, literature revealed no information pertaining to the effect of processing conditions on mechanical expression of oil from soursop seeds.

Going by the reports of Hamzat and Clarke (1993), in order to obtain a standardized process, it is pertinent to have an explicit knowledge and understanding involving the best steps and method of oil extraction method to be employed including check matting and controlling the processing parameters. This can be achieved through theoretical and experimental methods by modelling oil recovery from oilseeds. Also, interms of predicting oil yield, process parameters must be taken into consideration. In order to predict oil yield of soursop seeds at different process expression conditions, it is important to develop mathematical models.

Therefore, the objective of this research work isto establish the optimum processing conditions for the oil yield from mechanically expressed soursop seeds by optimizing the oil yield and process parameters using response surface methodology and also developing mathematical models relating oil yield to the process parameters.

II. MATERIALS AND METHODS

2.1. Experimental design

The effects of processing parameters (moisture content, heating temperature, heating time and pressing time) were investigated in order to establish the optimum processing conditions for the oil yield of mechanically expressed soursop seedand also develop mathematical models relating oil yield to the process parameters. These processing parameters were given appropriate consideration and properly checked in the course of this research study since they are very important and play significant role in obtaining high yield and has effects on the qualityof oil expressed from oilseeds when using mechanical method of oil expression.

The experimental design employed in this research work was a-4 factor, 5 levels, Factorial Central Composite Rotatable Design (CCRD) ofResponse Surface Methodology as adopted by (Fakayode and Ajav, 2016). Central Composite Rotatable Design constitutes mainly three types of design points which include: factorial points (nf), axial points (na) and central points (nc). The total number of treatment combinations in Central Composite Rotatable Design is $n = 2^k(n_f) + 2k\,(n_c)$ where 'k' represents the number of independent variables and n represents the number of repetition of experiments at the center point. The total number of design points in CCRD is represented as $N = 2^k + 2k + (n_o)$. The CCRD involved 30 experiments consisting of 2^4 factorial CCD, with 8 axial points (α = 2) and 6 replications at the centre points. Review of related literature and preliminary investigations formed the basis with which the independent variables were chosen. Five levels of pressing time (3, 4, 5, 6 and 7 mins) and moisture content levels of (10, 15, 20, 25 and 30 %wet basis) were chosen. Five heating temperature levels (50, 60, 70, 80 and 90^{o}C), five heating times of (10, 15, 20, 25, and 30 minutes) were also chosen.

2.2. Experimental procedures

Soursop (Annonamuricata) was purchased from Urua-Akpokpo market in Etinan Local Government Area of AkwaIbom State. The fruits were cut into pieces and the seeds removed from the pulps. The seeds were washed to remove particles from the pulp and then dried at room temperature. The seeds were manually cracked to get the kernel. Two (200) kernels were randomly selected from the whole samples for initial moisture content determination. The kernels were then oven dried in an air tight oven at a temperature of 105^{0}C for 6 hours, after they were allowed to cool and weighed. Continuous weighing was carried out at an interval of 30 minutes, until a constant weight was achieved (Oziokwu, 2012).

The moisture content was then calculated in wet basis using Eq.(1).

$$M_c = \frac{WW - DW}{WW} \times 100 \quad \text{Eq. (1)}$$

Where M_c = moisture content (%); WW = wet weight of sample or the initial weight of sample (g); DW = dry weight of sample or the final weight of sample (g).

The samples were conditioned to desired moisture content levels by oven drying method.
The conditioned samples were heated at different temperatures and times. Also, different pressing times were applied using a manually operated oil press (Figure 3) in the Food Engineering laboratory, University of Uyo. The oil yield was calculated using equation (2) as adopted by Fakayode and Ajav (2006).

$$Y = \frac{W_o}{W_g} \times 100 \quad \text{Eq. (2)}$$

Where Y = Oil yield (%);W_g= Weight of soursop (kg); W_o= Weight of oil expressed (kg)

Two (200)soursop kernels were collected, ground and dried. The ground and dried kernels were fed into the machine with the use of two circular nets, one attached into the machine after which the sample was poured in. The covering mesh was covered and the materials were then pressed by the movement of a plunger all the way down till it presses out the oil with the use of a screw jack. Thereafter, the oil started dripping beneath the machine (the outlet), thus, theexpressed oil was collected. After oil expression, the mechanical press was unscrewed with the use of a screw jack and the left over residue (cake) was removed. The oil was collected and weighed in a beaker.

2.3 Response Surface Methodology (RSM)

The experimental design employed in this study was carried out using design expert (version 6.0.0) software package so as to analyze and generate model equations for the expression process conditions. The data which was obtained through the experimental matrix was computed for the determination ofregression coefficient of the second order multiple regression models. The analysis of regression and variance was performed by the Design Expert. The models that were employed in analysing the expression process for soursop seed were linear, two factorial interaction(2FI), quadratic and cubic. The values that were obtained from the model were compared with the predicted values. The significanceand fitness of the model as well as the effect of significant individual terms and their interactions on the chosen responses were determined using Analysis of Variance (ANOVA). The P-value (probability of error value) was used as a tool to check the significance of each regression coefficient which also indicated the interaction effect of each cross product. SPSS window 20.0 software package was used to analyse the tests of between-subjects effects of processing conditions on oil yield. The experiment was repeated at the optimal conditions in order to validate the optimal parameters as recommended by Islauet al. (2002).

III. RESULTS AND DISCUSSION

Table 1 shows the result for the oil yield at various levels combination of moisture content, heating temperature, heating time and pressing time.

Thus, considering the range of all the expression process conditions employed in the expression process of oil from soursop seed, the highest oil yield of 29.42% was obtained at a moisture content of 15%wb, heating time of 25mins, heating temperature of 80^{o}C and pressing time of 6 mins, while the lowest oil yield of 16.83% was obtained at a moisture content of 20%wb, heating time of 20mins, heating temperature of 70^{o}C and pressing time of 3 mins as shown in Table 4.1. In comparison, Fakayode and Ajav (2016) while working on moringa seeds obtained an optimum oil yield of 28.58% at a moisture content of 11%(wb), heating temperature of 80^{o}C, heating time of 30 mins and applied pressure of 20 MPa while the lowest oil yield of 11.42%(wb) at a moisture content of 10%(wb), heating temperature of 70^{o}C and applied pressure of 5 MPA using mechanical method of oil expression (expeller). Udohet al. (2017) while working on soursop seeds obtained an optimum oil yield of 34.13% at a moisture content of 13.51%(wb) and lowest oil yield of 26.82%(wb) at a moisture content of 21.39%(wb), heating temperature of 70^{o}C and heating time of 30mins using soxhlet extraction method. Okoro (2013) obtained an optimum oil yield of 33.82%(wb) and lowest oil yield of 23.05% at a heating time of 30mins, heating temperature of 40^{0}C using soxhlet extraction method.

Going by the report of Orhevbaet al. (2013), it wasestablished that the method employed in oil extraction can cause variations in oil yield. Also, Anwar et al. (2006) reported that genetic and environmental factors can form the basis for variation in oil yield. Thus,increase in moisture content from 15-25% wet basisgave asignificant increase in oil recovery. However, further increase in moisture content up to 30% resulted to a diminution in the oil yield of soursop (Figures 3 to 5). Therefore, the optimum moisture content for soursop seed was found to be 15% wet basis for which an increase in moisture content results to a diminution in the oil yield (Figures 3 to 5). This trend conforms to earlier reports by Fakayode and Ajav (2016), on moringa, Olajide

(2000) on groundnut and sheanut, Bamgboye and Adejumo (2011) on roselle and Abidakunet al. (2012) on dika nut amongst others.

When the heating temperature was increased from 50 to 80◦C, there was a significant increase in oil yield anda decrease in oil yield was obtained when the heating temperature was increased up to 90◦C (Figures 4 to 7). When samples were heated at 50°C, the oil yieldwas considerablylower than the oil yield of those obtained when samples were heated at 60-80°C. This is as a result of insufficient heat treatment given tosamples during heating, thereby resulting to a decrease in oil yield.

There was a significant increase in oil yield as the heating time was increased to 25 mins, but further increase beyond this heating time resulted to a decrease in oil yield(Figures. 5 to 8). This is because when samples were heated at 50°C, more time was needed for thecoagulation of protein to take place, in the breakdown of oil-cells and in the adjustment of moisture content to optimum level, thus resulted to a decrease in oil yield. Whereas, samples heated at80°C needed a relatively shorter time to achieve all these processes, but further increase in heat treatment resulted to a decreases in the oil yield.Going by these results, research has proven that, at higher temperatures, coagulation of protein takes place faster and viscosity reduction is increased, thus resulting to an increased yield at short durations (Kagwacieand Anozie, 1995). The highest oil yield of 29.42% was obtainedwhen sample was heated at 80°C for 25 min (Figure 6). This trendconforms to the findings of Fakayode and Ajav on moringa seed, Adekola (1991) on coconut, Adeekoand Ajibola (1990) on groundnut, Olajide (2000) on groundnut and sheanut, Tunde-Akintundeet al. (2001) on soybean, Ajav and Olatunde (2011) on groundnut, Bamgboye and Adejumo (2011)on roselle and Abidakunet al. (2012) on dika nut amongst others.

There was a significant increase in oil yield when pressing time was increased up to 25mins, but oil yield decreased with an increased in pressing time of 25 30mins (Figures 5 to 8). This results conforms to the results of other oil expression from other oilseeds as reported by various researchers vizAdeeko and Ajibola (1990) on groundnut, Sivalaet al. (1992) on rice bran, Ajibolaet al. (1990) on melon seeds, Reddy and Bohle (1993) on mustard seeds, Olajide (2000) on groundnutandsheanut, Abidakunet al. (2012) on dika nut, BamgboyeandAdejumo (2011) on roselle amongst others.

3.1. Optimization of the expression process of soursop seeds using oil yield as response

The model was chosen based on the criteria for model selection as adopted by Fakayode and Ajav (2016), where the model must have the higher coefficient of determination (R^2), lower standard deviation values, insignificant lack-of-fit, maximum Adjusted R^2 and Predicted R^2 and model that is not aliased. To this end, the models that were suggested bythe Design Expert Software were linear and quadratic models. In terms of higher coefficient of determination (R^2) and lower standard deviation values, the quadratic model was finally selected ahead of the linear model to predict the oil expression process for soursop seeds (Table 2). Thus, the final equationis given as

$$Y = -41.35 + 4.03M_c - 0.17H_t + 0.76H_T + 0.60P_T - 0.06{M_C}^2 - 0.05{H_t}^2 - 0.01{H_T}^2 - 0.83{P_T}^2 - 0.01M_C H_t - 0.01M_C H_T - 0.07M_C P_T + 0.03H_t H_T + 0.12H_t P_T + 0.11H_T P_T \quad (7)$$

(Std. Dev. = 1.93, R^2= 0.8477, Mean = 22.44, AdjR^2= 0.7056, C.V. = 8.61, Pred.R^2= 0.1297, PRESS = 320.42, AdeqPrecision = 9.544).

Where $Y =$ Oil yield, % ;M_c= Moisture content, % w. b;H_T= Heating temperature, ℃;
H_t= Heating time, mins. ;P_T= Pressing time, mins.Std. Dev. = Standard deviation, C.V. = Coefficient of Variation, PRESS = Predicted Sum of Square, Adeq. Precision = Adequate Precision.

The positive terms in the model equation indicates that there is a direct relationship between processing conditions and interactions with yield, while the negative terms represents an indirect relationship between processing conditions and interactions with yield. Therefore, it was revealed that moisture content, heating temperature, heating time and pressing time all have a direct relationship with oil yield. Increase in moisture content, heating temperature, heating time and pressing time results to an increase in oil yield. Also, it was ascertained that moisture content is the most important factor affecting oil yield from soursop seeds. This is in agreement with the findings of Fakayode and Ajav (2016) on moringa seed, Aremu and Ogunlade (2016) on African oil bean seed, Matthaus (2012) on oil crops, Olajide (2000) on groundnut and sheanut , Akinoso (2006) on sesame seeds, Orhevbaet al., (2013a) on neem seed and Southwellet al., (1990) on avocado.

The Model F-value of 5.97 implies that the model is significant. Values of "Prob> F" less than 0.0500 indicate model terms are significant. In this case A, B, A^2, B^2, C^2, D^2, BC, CDare significant model terms (Table 3). This implies that the moisture content, heating temperature, heating time and pressing time all have significant effects on oil yield with the moisture content having the greatest influence on oil yield. To this end, it was established that, the four expression process conditions influenced the quantity of oil recovery from soursop seeds. Values of "Prob> F" greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 48.64 implies the lack of fit is significant. It was found out that the model was significant with a low probability value (0.0002) and a satisfactory coefficient of determination (R^2 = 0.8477). The high coefficient of determination showed excellent correlations between the independent variables. This value indicates that the response model can explain 84.77% of the total variability in the responses.

The statistical analysis test of between-subjects effects on the percentage oil yield of soursop seed at 5% level of significance as presented in Table 4, showed that the individual factors as well as the two factors interaction were all significant, but the three factor interactions were not significant except the interaction among the heating temperature, heating time and pressing time. This analysis shows that all the expression process variables used for the oil expression process of soursop seed have significant effects on the yield with a mean value of 21.626 having a lower standard error of 0.066 at 95% confidence interval (Table 4).

3.2.Validation of model

The optimization process for the goal of maximizing the optimum value of the oil yield during the expression process of soursop seed in a mechanical screw press was performed. From the optimization result for the maximum optimum predicted value of the oil yield as shown in Figure 10, in the range of 10-30% moisture content (wet basis), 50-90^{o}C for heating temperature, 10-30 mins for heating time and 3-7 mins for pressing time, the maximum predicted optimum oil yield of 29.38% and desirability of 100% at optimal moisture content of 16.52% w.b, heating time of 22.35 mins, heating temperature of 82.56^{o}C and pressing time of 6.57 mins was obtained.

A test run under the obtained optimal expression process conditions of 16.52% w.b, 22.35 mins, 82.56^{o}C and 6.57 mins for moisture content, heating time, heating temperature and pressing time respectively, was carried out in order to validate the quadratic model for oil yield of soursop seed, an experimental percentage oil yield of 29.34% was obtained.

In comparison of the predicted and experimental results for the optimum oil yield of soursop seed using a mechanical screw press, it can be seen that there was an excellent agreement between the observed and predicted values for the oil yield of soursop seed obtained from the parity plot (Figure 11) between the actual and predicted values. The correlation between the predicted and experimental values for soursop oil yield gave an R^2 value of 0.8477 which indicated that the predicted values and experimental values have a reasonable agreement. The deviation between predicted and experimental values is low and ranged between 0.01- 4.07. Hence, the generated quadratic model has the accuracy to predict the oil yield of soursop seed using a mechanical screw press.

IV. CONCLUSIONS

The oil expression from soursop seed at various process conditions using mechanical method was investigated. The study advocates that soursop seed is a source rich in oil. From the Design Software employed and the range of variables considered in this study, the highest oil yield of 29.42% was obtained when soursop seeds were conditioned to a moisture content of 15% wet basis, heated at 80^{o}C for 25 mins at a pressing time of 6 mins. Predicted optimum oil yield of 29.38% at moisture content of 16.52% wet basis, temperature of 82.56^{o}C, duration of 22.35 mins and pressing time of 6.57 mins was obtained. Under these optimal conditions, the experimental value was 29.38% which was in agreement with those predicted by computation. The deviations between experimental and predicted values ranged from 0.01- 4.07 for oil yield. It was established that the processing parameters (moisture content, pressing time, heating temperature and heating time) influenced the quantity of oil recovery from soursop seeds. In the light of this, a model equation was generated with a satisfactory coefficient of determination (R^2 = 0.8477). The coefficient of determination demonstrated an excellent correlation between the independent variables. Mathematical models were developed relating processing factors to oilyield.Thus, considering the range of variables studied, the model chosen adequately predicted the yield for soursop seed oil expression.From the result of this study, it is established that the oil of soursop seed oil could serve as feed stock in many industrial applications.

Conflict of Interest -Authors declare no conflict of interest.

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Figure 1. Soursop Fruit

Figure 2. Soursop Kernel

Figure 3. Mechanical Screw Press

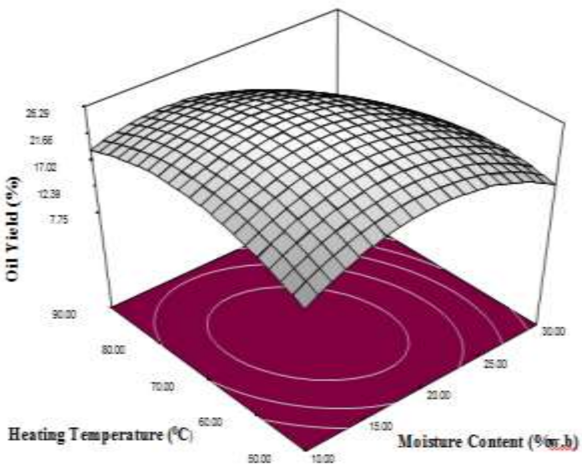

Figure 4. Effect of heating temperature and moisture content on oil yield.

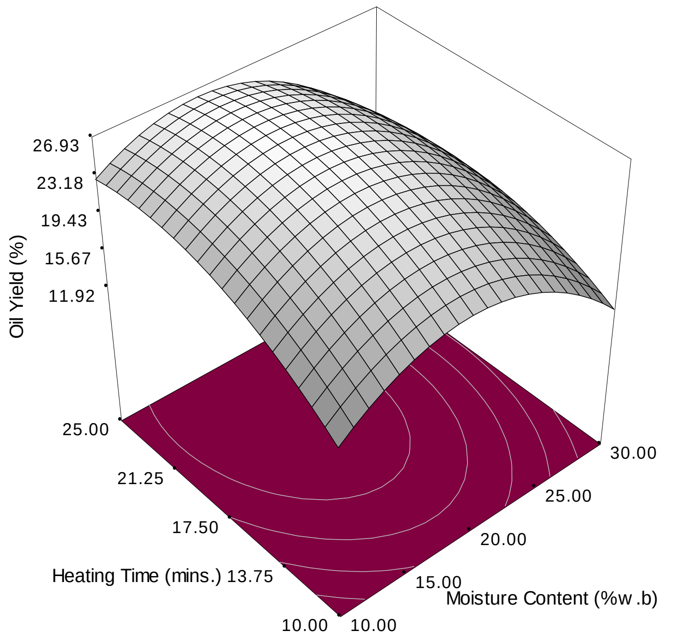

Figure 5. Effect of heating time and moisture content on oil yield.

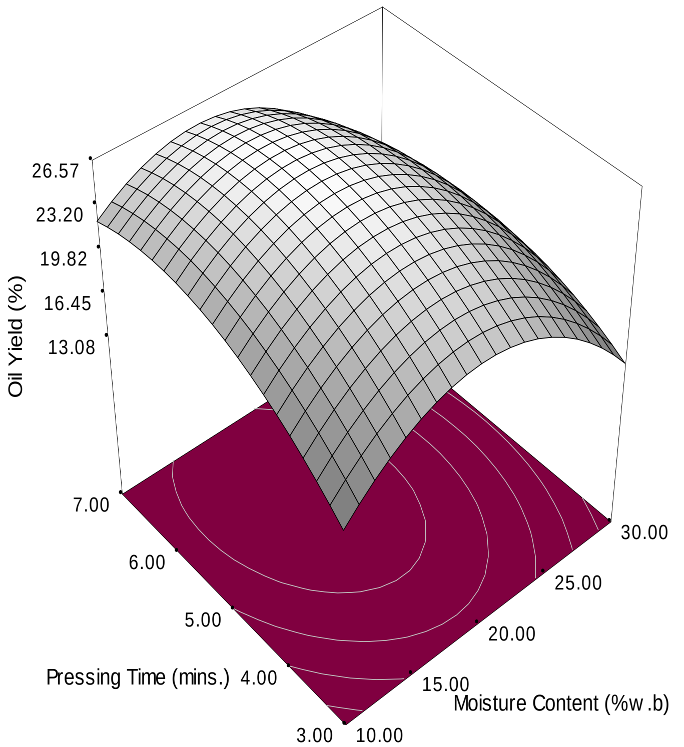

Figure 6. Effect of pressing time and moisture content on oil yield.

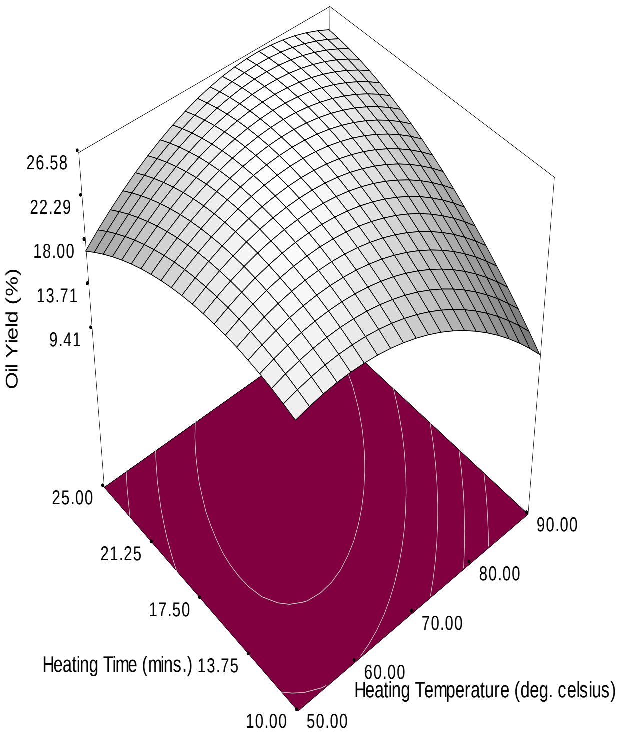

Figure 7. Effect of heating time and heating temperature on oil yield.

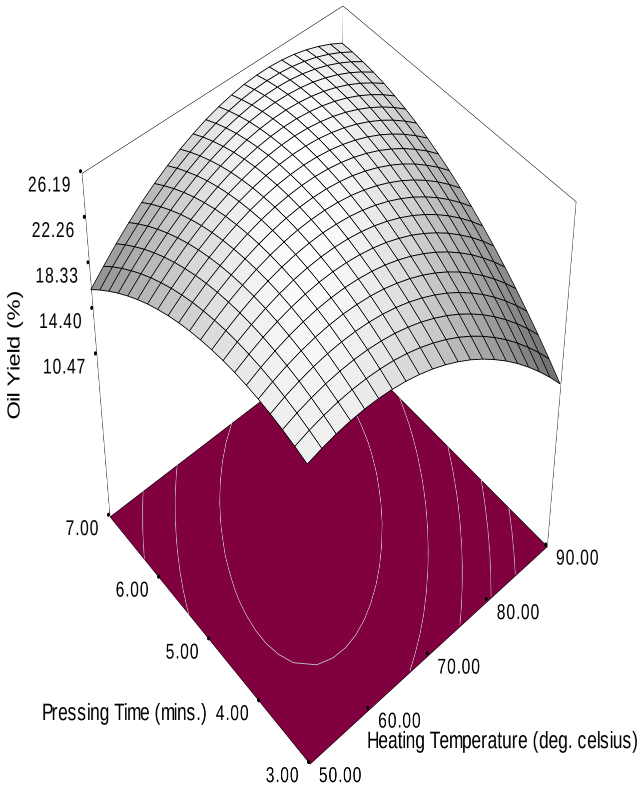

Figure 8. Effect of Pressing time and heating temperature on oil yield.

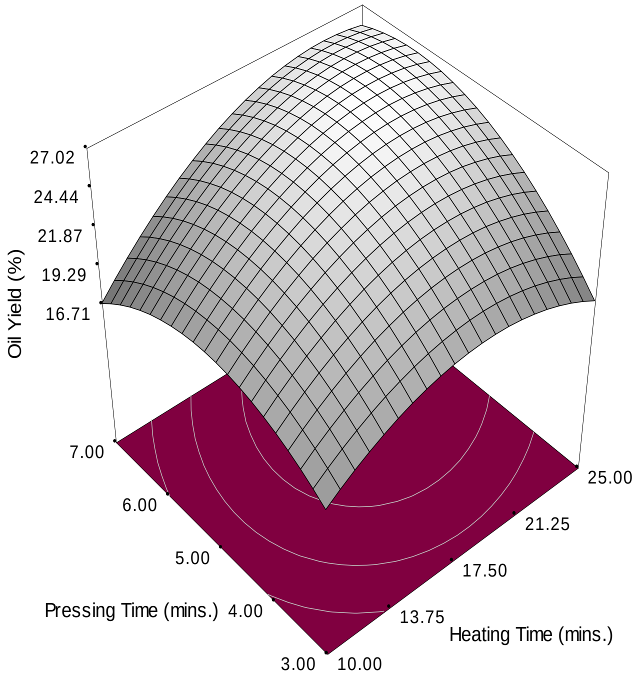

Figure 9. Effect of Pressing time and heating time on oil yield.

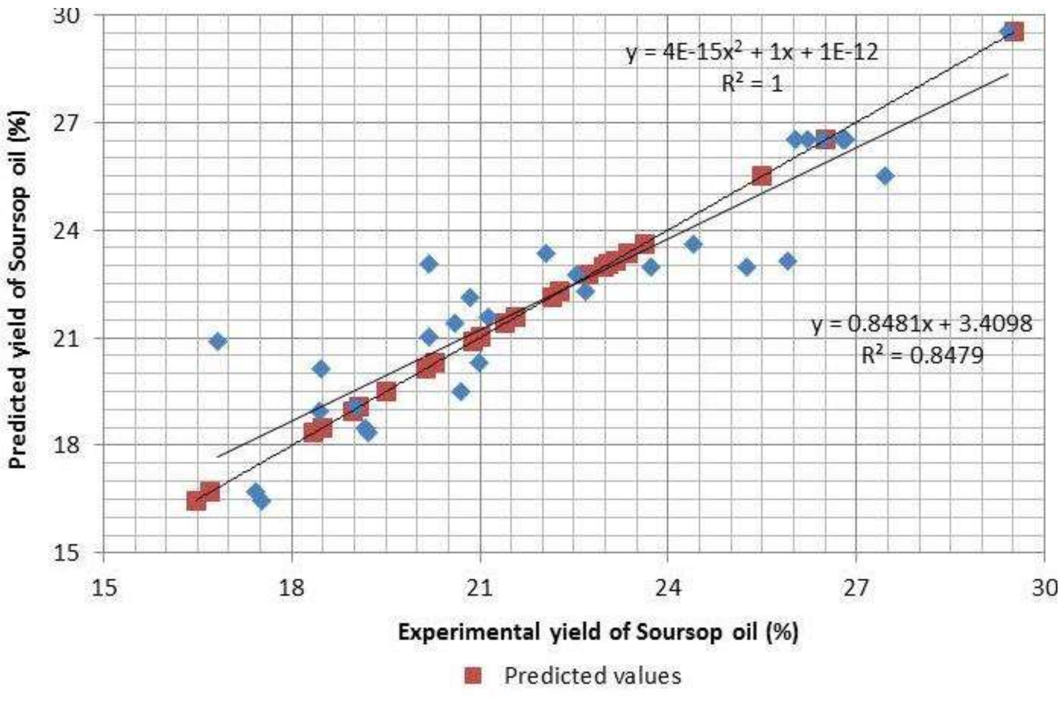

Figure 10. Ramp for optimization of expression process conditions for oil yield of Soursop seed.

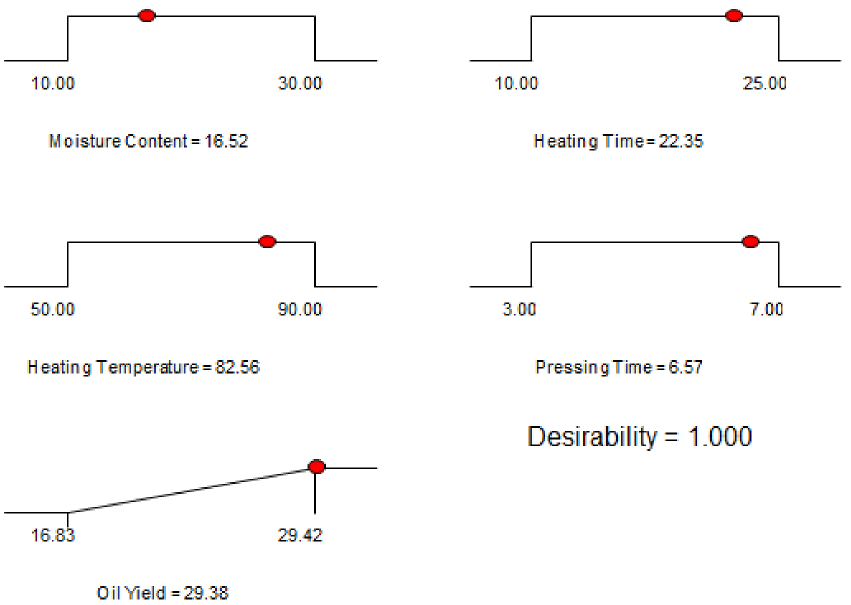

Figure 11. Predicted and actual values for oil yield from soursop seed.

Table 1.Oil Yield of Soursop at Various Expression Process Conditions.

Runs	**Moisture Content (%)**	**Heating Time (mins)**	**Heating Temperature (°C)**	**Pressing Time (mins)**	**Oil Yield (%)**
1	20	20	70	3	16.83
2	15	15	60	4	25.91
3	25	15	60	4	23.73
4	15	25	60	4	20.99
5	25	25	60	4	19.16
6	15	15	80	4	20.69
7	25	15	80	4	17.51
8	15	25	80	4	25.26
9	25	25	80	4	19.21
10	20	20	50	5	20.59
11	20	10	70	5	18.47
12	10	20	70	5	20.19
13	20	20	70	5	26.83
14	20	20	70	5	26.77
15	20	20	70	5	26.23
16	20	20	70	5	26.79
17	20	20	70	5	26.02
18	20	20	70	5	26.45
19	30	20	70	5	17.43
20	20	30	70	5	21.12
21	20	20	90	5	20.83
22	15	15	60	6	22.54
23	25	15	60	6	20.19
24	15	25	60	6	22.68
25	25	25	60	6	18.45

26	15	15	80	6	24.40
27	25	15	80	6	19.03
28	15	25	80	6	29.42
29	25	25	80	6	22.05
30	20	20	70	7	27.45

Table 2.Comparison of models

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	3.30	3.18	1.93	1.44
Mean	22.44	22.44	22.44	22.44
C.V.	14.71	14.19	8.61	6.44
PRESS	376.17	332.61	320.42	2022.79
R^2	0.2604	0.4769	0.8477	0.9603
Adjusted R^2	0.1420	0.2016	0.7056	0.8356
Predicted R^2	-0.0217	0.0966	0.1297	-4.4942
Adequate precision	4.858	6.767	9.544	9.721

FI= Factorial Interaction, Std. Dev. = Standard deviation, C.V. = Coefficient of Variation, PRESS = Predicted Sum of Square, Adeq. Precision = Adequate Precision

Table 3.ANOVA for response surface quadratic model.

Source of Variation	Sum of Squares	df	Mean Square	F-value	Prob> F
Model	312.11	14	22.29	5.97	0.0007*
A	33.56	1	33.56	8.98	0.0090*
B	40.12	1	40.12	10.74	0.0051*
C	6.50	1	6.50	1.74	0.2069
D	12.48	1	12.48	3.34	0.0876
$\mathbf{A^2}$	75.73	1	75.73	20.27	0.0004*
$\mathbf{B^2}$	54.95	1	54.95	14.70	0.0016*
$\mathbf{C^2}$	38.62	1	38.62	10.34	0.0058*
$\mathbf{D^2}$	18.86	1	18.86	5.05	0.0402*
AB	2.56	1	2.56	0.69	0.4208
AC	8.09	1	8.09	2.17	0.1618
AD	2.31	1	2.31	0.62	0.4440
BC	40.32	1	40.32	10.79	0.0050*
BD	5.83	1	5.83	1.56	0.2307
CD	20.61	1	20.61	5.52	0.0330
Residual	56.06	15	3.74		
Lack of Fit	55.49	10	5.55	48.64	0.0002*
Pure Error	0.57	5	0.11		
Cor Total	368.17	29			

Arepresents moisture content; B represents heating temperature; C represents heating time; D represents pressing time. *Significant.

Table 4.Tests of between-subjects effects of processing conditions on oil yield.

Source	Type III Sum Squares	ofdf	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	367.597[a]	24	15.317	134.273	.000	.998
Intercept	5583.504	1	5583.504	48948.047	.000	1.000
MC	159.119	3	53.040	464.975	.000	.996
HT	71.897	3	23.966	210.096	.000	.992
Ht	51.536	3	17.179	150.598	.000	.989
PT	87.584	3	29.195	255.936	.000	.994
MC * HT	2.560	1	2.560	22.442	.005	.818
MC * Ht	8.094	1	8.094	70.957	.000	.934
MC * PT	2.310	1	2.310	20.254	.006	.802
HT * Ht	40.323	1	40.323	353.489	.000	.986
HT * PT	5.832	1	5.832	51.128	.001	.911
Ht * PT	20.612	1	20.612	180.693	.000	.973
MC * HT * Ht	.697	1	.697	6.112	.056	.550
MC * HT * PT	.116	1	.116	1.013	.360	.169
MC * Ht * PT	.055	1	.055	.484	.518	.088
HT * Ht * PT	2.341	1	2.341	20.522	.006	.804
MC * HT * Ht * PT	.601	1	.601	5.265	.070	.513
Error	.570	5	.114			
Total	15475.673	30				
Corrected Total	368.168	29				

a. R Squared = .998 (Adjusted R Squared = .991)

[a]= Significant

1. MCrepresents moisture content.
2. HT represents heating temperature.
3. Ht represents heating time.
4. PT represents pressing time.

Ossom, Inimfon Samuel. "Process optimization of mechanically expressed soursop(Annonamuricata) seeds oil using response surface methodology" *The International Journal of Engineering and Science (IJES)*, 9(01) (2020): 01-13